Event-by-event extraction of kinetic and chemical freeze-out properties in the CBM experiment*

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The future CBM experiment at FAIR is designed to study properties of strongly interacting matter produced in heavy-ion collisions at high baryon densities. It will employ high intensity beams and large acceptance detectors. One important task is to extract the thermal parameters of matter at stages of kinetic and chemical freeze-out from the observed data. The extraction of thermal parameters is implemented as a package within the CBMROOT framework.

The kinetic freeze-out temperature of charged pions is extracted from their measured momentum spectrum. In the simplest scenario the particles are assumed to have a Boltzmann momentum distribution with no collective flow. To test the method, a 1000 Monte Carlo (MC) events with thermally distributed pions ($T = 128$ MeV) were generated and then processed in CBMROOT. Reconstructed STS Tracks, as well as the initial MC Tracks, were used to calculate the average transverse mass of pions $\langle m_T \rangle$, which was then used to estimate the temperature. Due to limited detector acceptance, and due to imperfect reconstruction efficiency, the mean transverse mass of STS tracks differs from the MC one. Therefore, an appropriate correction was performed using the known momentum dependence of acceptance function and reconstruction efficiency. Figure 1 depicts the extracted Boltzmann temperature on the event-by-event level. It is seen that the extracted temperature has a Gaussian-like distribution around the theoretical value of 128 MeV when one uses MC Tracks (blue line) or STS Tracks with proper correction on acceptance (red line). If one neglects this correction on acceptance then one gets essentially different (incorrect) value of temperature (green line). The procedure, developed for this model, can be used as a basis for analysis in the framework of more complex and more realistic models.

The parameters of the chemical freeze-out are extracted by fitting the measured particle ratios in the framework of the Hadron Resonance Gas model. All strange and non-strange hadrons which are listed in the Particle Data Tables are included and the model is implemented in CBM-ROOT and works similarly to the THERMUS package [1]. The grand canonical ensemble formulation is used and excluded volume corrections are included in the framework of the thermodynamic mean-field approach [2]. The fit can be performed on event-by-event level and also on the inclusive spectra level. Figure 2 shows the extracted temperature and baryonic chemical potential from MC events generated in the thermal model with $T = 100$ MeV and $\mu_B = 550$ MeV. For each parameter extraction a set of 10 events was used, and the fit error estimates were calculated and depicted as well. The extracted values are consistent with the theoretical input.

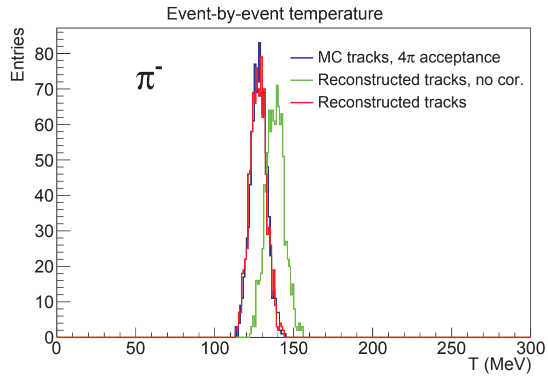

Figure 1: The temperature of pions extracted on event-by-event level using the MC tracks (blue line), STS tracks without acceptance correction (green line), and STS tracks with correction on acceptance (red line).

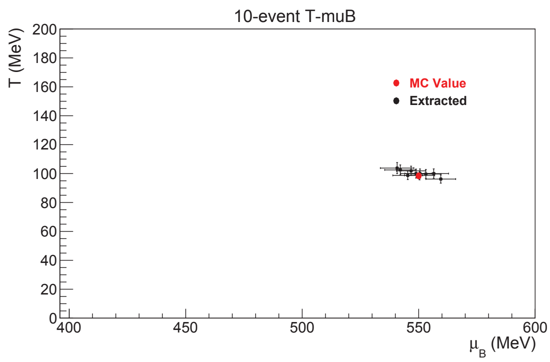

Figure 2: The temperature and the baryonic chemical potential extracted from the 10-event sets in the framework of the Hadron Resonance Gas model. The theoretical MC values is shown by the red dot.

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References

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